7-2007

Writing for Understanding in Math Class

Linda Moore
Lexington, NE

Writing for Understanding in Math Class

Linda Moore
Lexington, NE

Math in the Middle Institute Partnership
Action Research Project Report

in partial fulfillment of the MAT Degree
Department of Mathematics
University of Nebraska-Lincoln
July 2007

Writing for Understanding in Math Class

Abstract

In this action research study of my classroom of 10th grade geometry students, I investigated how students learn to communicate mathematics in a written form. The purpose of the study is to encourage students to express their mathematical thinking clearly by developing their communication skills.

I discovered that although students struggled with the writing assignments, they were more comfortable with making comments, writing questions and offering suggestions through their journal rather than vocally in class. I have utilized teaching strategies for English Language Learners, but I had never asked the students if these strategies actually improved their learning. I have high expectations, and have not changed that, but I soon learned that I did not want to start the development of students' written communication skills by having the students write a math solution. I began having my students write after teaching them to take notes and modeling it for them. Through entries in the journals, I learned how taking notes best helped them in their pursuit of mathematical knowledge.

As a result of this research, I plan to use journals more in each of my classes, not just a select class. I also better understand the importance of stressing that students take notes, showing them how to do that, and the reasons notes best help English Language Learners.

The purpose of this research is to encourage students to express their mathematical thinking clearly by developing their communication skills. In my own education I have discovered how useful it is to understand why I do the things required to solve math problems as opposed to only realizing how they are done. I expect my students to internalize the thinking skills that result from applying mathematics.

During whole class instruction, I usually see students listening or sitting quietly. Sometimes they are engaged in other activities. While some students are working on problem solving during guided practice, others are visiting with friends. I believe if homework is getting done, it is being copied and handed around because not all students can verbalize a correct explanation of their thought processes when asked why they got an answer. Yet, they do not ask for help from me. When I ask how I can help them get started, they defer any assistance.

Students obviously appear to lack motivation to understand the subject matter. I believe if they understand their own thought processes it will motivate them to learn better. The drawback is I do not know what level they are cognitively, and I cannot ask guided questions unless I know how far along they are in their knowledge base. There is a need to develop communication skills so that I can determine their level of cognition. Then I can analyze their thinking, apply appropriate teaching strategies, or ask pertinent questions to further their education.

I sought to implement basic communication in my classroom: Can my students write? Can my students speak? I expect them to use mathematical terms as if they were using common language to precisely express ideas. The importance of this on a larger scale is that students will then be able to exchange mathematical ideas effectively with others. They will be able to share ideas and build on the work of others. Students need to be able to communicate in such a way that anyone, especially a peer, can understand their written purpose and work, as well as

understand the explanation of why their solutions make sense. People who are able to express their ideas successfully verbally will gain confidence and learn to overcome their fear of not understanding math.

Communication is important because it will show at what level the student understands the concept or skill in a wide variety of situations. It will show if the student understands the concept in order to learn a new topic that may be related to a current one. It can demonstrate if a student understands a frequently used skill and if it is an important strategy. Also, it will show if there is an error in thinking, and we will be able to discuss and correct such errors.

Problem Statement

The problem of communication struggle is worth exploring because to guide curricular and instructional decisions, one needs to know *how* students learn in order to promote student cognition in mathematics. The purpose of the study is to encourage students to express their thinking clearly by developing their communication skills. While writing will be used to implement communication within classes, both oral and written communication will be utilized in order to organize and consolidate thinking.

Since state standards have debuted, the unspoken rule has been for teachers to include a rigorous review of assessment topics in their curriculum, in the hope that test scores will improve. Although Middleton schools do not have a test such as the Texas Assessment of Academic Skills where teacher pay is tied to test scores, instructors in Middleton do feel the pressure to raise test scores. This push is especially evident now that Middleton has an extremely diverse ethnic population.

Testing is not teaching. According to Harlen & Crick's study (2003), "Research shows high stakes tests do not have a positive effect on teaching and learning in the classroom". In fact,

something Middleton Public Schools is particularly interested in is a statistic showing high stakes testing programs have been shown to increase high school drop out rates—particularly among minority student populations.

Literature Review

The current spotlight on legislation to develop a state test draws attention to the first idea for this research. Middleton Schools have fallen into the trap of "teaching to the test." But is testing teaching? Harlen and Crick (2003) conducted a five-year study, investigating the motivation for learning among minority student populations. Their study encompassed high stakes, high-standards testing and its impact on minority and economically disadvantaged students. Harlen and Crick assert students do not learn through taking tests. They write, "high stakes, high-standards tests do not have a markedly positive effect on teaching and learning in the classroom" (Harlen & Crick, p. 172).

In fact, "high stakes testing programs have been shown to increase high school drop out rates—particularly among minority student populations," according to Madaus and Clarke (1999, p. 1), as quoted by Harlen and Crick (2003, p. 173). Given the diverse student population of Middleton high school, this is an important fact to consider.

If testing in and of itself does not teach students, how else then do students learn? Could it be a method as simple as the teacher taking an interest in the student as a person, that is, trying to understand where the student came from, and is a key trying to make connections with his or her prior knowledge? McCaughtry (2005) completed a case study about a high school physical education teacher who came back to teach in her hometown. At the time, however, the school was under a federal mandate requiring racial integration. The school was experiencing racial segregation among both teachers and students. The purpose of this study was to examine how

this teacher understood her students and then made decisions about content, curriculum and pedagogy. McCaughtry writes in part concerning methodology, “to understand and work effectively in an individual moment with a student, a teacher must have some sense of the totality of the child’s previous experiences” (McCaughtry, p. 380). This research included journaling to allow students to connect with the instructor in order to learn about previous experiences.

Underlying this is the notion that how one teaches students of diversity has changed through the past few years.

> Finally, they all prescribe teaching that is explicit and extensive, with a great deal of supervised student practice and provision of feedback. Teachers are viewed as agents who can foster generalized strategy and provide guidance and reminders about when and how strategies can be extended to new situations (Pressley, Symons, Snyder & Cariglia-Bull, 1989, p. 22).

How much do students learn when the teachers are the facilitators of the classroom, spewing forth strategies for students to use? The more recent methodology of teaching with a strategy of understanding the student, and where they are coming from, should be a basis for the research topic of writing for understanding. Writing will make connections to the past and encourage students to discuss and discover mathematics with each other and with the instructor. A student journal provides a discrete method of communication from student to teacher without fear of disclosure to other students. Some students preferred communication through a journal rather than taking a chance to speak in class and seemingly appear less knowledgeable grammatically or mathematically.

An item of interest often revealed in student journals highlights how many students do not *listen* to a teacher’s explanation. Instead they consider it just another *procedure* for them to learn (Buerk, 1993, p. 5). This quote was taken from Buerk’s address given at Mathfest, the

Mathematical Association of America's summer session in 1998 in Toronto, Ontario, Canada. This researcher questioned the fact that her students in this study considered it just another procedure for them to learn, but is it just another hurdle in working with students of diversity? The majority of students in this research belong to an ELL population. Research does not address the specific issue of how to best address a diverse ELL high school mathematics classroom.

Buerk stresses, "I want us to think about what our students hear, which is often not what we are trying to convey," (Buerk, 1993, p. 4). Her article encourages teachers to listen carefully to what students say. What students hear is often not what a teacher intends and obscures their mathematical thinking. Buerk suggests teachers have the students *talk* and *listen* to each other. As an instructor, she proposes having the students write metaphors for mathematics. By listening to what the student is saying, one can understand how he or she thinks mathematically. But a teacher must be very sure what his or her personal opinion of mathematics is, or it can give students the wrong impression, thus coloring their way of thinking. A student's question may no longer be phrased in the proper perspective. This may lead him or her to stop asking questions out of embarrassment (Beurk, p. 10). Student journals from this study reflected this data as recorded by this student, "I'm very shy at asking questions during class or answering them for that matter, afraid to get it wrong."

Finally, some literature shows the closely related factors of language and communication. Students may not even realize the best results precipitating from teaching that leads to high cognition because of a language/communication barrier. Stonewater researched prospective middle school teachers' perception of a "best math class" as a result of the Glenn Commission Report (U.S. Department of Education, 2000). In Stonewater's study, students progressed from believing the best math class is one where a teacher gives adequate examples and spends time

going over the examples, to viewing studying with a group of students to be more valuable. "Students went from believing that watch, learn and practice type of learning mathematics was the best way to making math instruction (their) own." Part of the "making math instruction your own," has to do with language, and therefore, communication. Allowing students to talk things out and question each other in their own vernacular will deepen their understanding of mathematics. This was acutely pointed out in Middleton student journals. This single fact was the most eye-opening part of the research results that were gathered. Students were able to communicate their feelings about why a journal is important in learning math through quotes like, "Why it's important to ask for help and how we use basic math everyday," "I like writing in a journal because you actually take time to explain yourself and it helps you have more information about how to solve problems," "It helped a lot. It gave you better understanding and it's not just like you go over each problem quickly. You actually take your time on a problem, you write in a journal, and you can go back if you don't remember how to solve a problem you've written down, so you have a reference basically."

Promoting language and communication may be difficult. As one account by Neria and Amit (2004) notes, very few students choose to exchange ideas using algebraic representation. Those students who do are the higher achievers. Neria and Amit based their findings on their analysis of 350 answers to problems that demanded communication of reasoning, explanations, and justifications that ninth-graders chose in order to communicate their problem solving paths and justifications. Another consideration involves a student's native language. Dominguez recorded results showing how second-grade bilingual students were able to articulate their mathematical reasoning through gestures and speech. Dominguez reports, "Teachers can benefit to parallel attention of verbal and non-verbal communications. How students articulate math

reasoning through gestures [may be helpful]" (Dominguez, 2005, p. 291). Interestingly, one student in this research chose to communicate exactly that way. She would use gestures to communicate her thoughts, yet she was eloquent in writing her thoughts and ideas in her journal. Logically it would follow that language/communication, either oral or written, would help students deepen their knowledge of mathematics. Baxter, Woodward and Olson conducted research in a yearlong study incorporating middle level special education students in problem solving situations in math class. Their 2005 article notes that writing offers an alternative to classroom interaction. Having students write in math class helps develop communication and strengthen mathematical reasoning. Promoting this concept though difficult seems to result in benefits worth the task. Data collected from the pre- and post-tests support this.

Concentrating on students' language and communication barriers by utilizing the written word, or in some cases, even the ability to use gestures, may bring students to a stronger understanding of mathematics. However, as Baxter, Woodward and Olson (2005) suggest, journals are an important form of classroom communication too. Alcaro, Alston and Katims (2000), who conducted research with fourth-grade students about how children think mathematically indicate journals are not only important in terms of language and communication, but they also provide a way to know when students (and so how) students are thinking.

On the other hand, are journals the only acceptable form of writing? Perhaps formal essays, writing prompts, creative writings, explanations and justifications could be used as well. Although implemented for only one short semester, all of these forms were used in this research and results recorded. Anything is desirable that will encourage students to improve their ability

to summarize what has been taught, discuss both ideas and thinking, and to ask questions and collect examples.

Bishop (2006), who has spent over fifteen years researching mathematical education in its cultural context, has focused on two topics, cultural interfaces in mathematics education and values in mathematics education. Bishop's research (p. 119) focused on the need to explore how the mathematics curriculum can be made more culturally responsive in order to encourage more participation at higher levels particularly among cultural minority groups. He suggests that the learner must not only face changes in language, but in knowledge. This is another example of the need for individuals to construct his or her knowledge by personalizing it. This research precipitated the journal stem, "How are you going to use what you learned about how you learn in your classes in the future?" Student responses include things like "I learned that the way I learn best is by notes and examples," "I learned a lot from my classmates around that could help me out," "I learned by hands-on examples." Students were encouraged to be assertive and ask for help in ways they best understand.

This researcher found the language barrier added a level of complication when it comes to communicating mathematics. One surprise discovery was made when she realized that students were unfamiliar with taking notes. When taught to work with ELL students one is often told just because the student can use the word, doesn't mean they understand its meaning. This was acutely brought into focus when the teacher became aware that the student definition of writing the thought process of problem solving was often referred to as "taking notes." The teacher was pleased the students recognized the benefit of becoming aware of that learning strategy, as one student writes in her final journal piece,

> My best way of understanding my homework is by taking notes. I think that taking notes will help me in all of my other classes. This learning technique will help me all of the time

in every year in school.

Using a written form of communication helped convey exactly how a student was overcoming language and communication barriers. The instructor gained insight into how thoroughly a student understands. It will give a teacher the ability to guide or apply alternatives. The goal began by using written communication to show a teacher what student understanding was compared only to numerical problem solving. It was intended to show the teacher *how* the student overcomes language and communication difficulties, to see the frustrations involved with how they learn math. Information collected included the teacher's awareness of how investigations must be clear to both student and teacher. When working with students of ELL background there is a need for feedback on the student's understanding of the intended investigation questions.

In order for these things to come into focus, most important is the construction of each student's personal knowledge. Alas, the first unexpected barricade encountered was the fact that students did not know how to take notes. The best way to do that may not be through testing. It may not be through methodology that develops a closer bond with the teacher who seems to appreciate the student's background. But there is a connection. The promotion of thinking mathematically, and breaking through language and communication barriers conjoins with the others when the importance of writing in the classroom is seen as a beneficial concept as well. By teaching students how to take notes, they were better equipped to compose in journals, or incorporate other forms of writing, and in turn, learn to formulate, clarify and relate concepts. They practice problem solving. They come to a better understanding of mathematics and learn how to articulate their thinking processes. They learn to communicate with peers.

When students learn to explain mathematics in written form, a teacher can more accurately check for overall understanding or cognition. The student also gains confidence in his or her work. This confidence relates directly to their knowledge of mathematics so that they learn to question themselves or each other—rather than the teacher—when they do not understand. Through writing, the goal is to develop better cognition. This will also lift the teacher's level of understanding of how students think mathematically. Ultimately, the teacher then can see the students both as individuals and as learners leading them to achieve a better, more meaningful education.

This research project differs from the published literature in several ways. This research involved high school geometry students. The students in the literature were predominantly elementary students or middle school students with one study focusing on algebra students. Also, while this research investigates written communication (taking notes), most published research instead investigated student journals. While Harlen and Crick (2003) studied minority students in math classes, they also studied special education students and how they learn math as did Baxter, Woodward and Olson (2005). This study was on regular education students in a geometry classroom made up demographically of racial diversity. McCaughtry (2005) studied a teacher who worked with racial controversy in her school and used journaling to better understand her students in order to build curriculum. That teacher was a physical education instructor while this research was done in a mathematics classroom. Stonewater (2005) studied future middle school teachers and explored what they considered the ideal math class. This research was about high school students still in the mathematics class. Alcaro, Alston and Katims (2000) studied fourth graders and how they think mathematically as did Neria and Amit (2004) who studied ninth graders and how they communicated mathematical reasoning, explanations and justifications of

math solutions using personal math journals. This research specifically studied high school geometry math solutions in the context of taking notes and writing explanations of math solutions. Dominguez (2005) studied second graders and how they use gestures to communicate mathematically. While this researcher found students using gestures, they were students from a high school integrated ELL classroom. Bishop (2002) a veteran of math education and cultural interfaces studied mathematics as it relates to cultures, whereas this research was conducted on a diverse population, not one specific culture.

Purpose Statement

The purpose of the study is to investigate whether student understanding will increase through writing. Students will be encouraged to express their mathematical thinking clearly by developing their communication skills. The variables of student ability to communicate mathematically will be examined in the research. Homework alone did not satisfy the desire to understand where students were in their mathematical learning. Students could not answer the question of why they got an answer. Yet, they did not ask for help from the instructor. When asked how the instructor could help them, they deferred any assistance. Some English Language Learners seem to lack motivation to understand the subject matter. If they understand their own thought process would it motivate them to learn better? Teachers do not know where students are in their learning if the students refuse to communicate. It becomes very difficult to ask guided questions unless the instructor knows where students stand presently in their knowledge base. In this age of accountability, there is a need to develop communication skills so that educators can determine their students' level of cognition. Only then can a teacher analyze their thinking, apply appropriate teaching strategies, or ask pertinent questions to further their education.

The intervention implementation was intended to be that of basic communication. Can the students write? Can they students speak? The expectation was for students to use mathematical terms as if they were using common language to precisely express ideas. The importance of this on a larger scale is that students will be able to exchange mathematical ideas effectively with others. They will be able to share ideas and build on the work of others. Students need to be able to communicate in such a way that anyone, especially a peer, can understand their purpose and process, as well as understand the explanation of why their solutions makes sense. People who are able to express their ideas successfully will gain confidence and learn to overcome their fear of not understanding math.

Questions for research are: What are the effects on student understanding of having students write explanations to math problem? How do students communicate their understanding/frustrations of how they learn mathematics? What are the effects on students' attitudes toward mathematics of students writing math journals? Other questions that came from those points were: What can students really know and do mathematically? Can students communicate what they think? What words appear in their communication that will allow the teacher to know they have reached a benchmark of the concept? Which method gathers better data, free writing or teacher prompts? How can the teacher gather meaningful information and how will evidence be used? How do students understand? How do they know when they understand something? How does the teacher know when the student understands something? Will the teacher need more than just writing explanations? If so what? Most importantly, what one type of communication will give the teacher the best result?

Method

The most frustrating part of collecting data was the language issue. Some students' parents did not have a permission letter in their own language. Due to a minor mix-up, all permission letters were not mailed in February, 2007, but finally March 21, 2007, it was necessary to ask other students to translate in Spanish the parent letter that accompanied the permission form. The parents who spoke Japanese, Vietnamese and Swahili had to rely on their own student to translate the permission paper and parent letter.

Frustration level rising, classroom-writing processes were changed before official data collection began with parental consent. Early in February, a student "free write" was conducted after journals were handed out. Composition notebooks were kept in the classroom and handed out each day. Some opted to keep them and bring them to class each day. Students' writings were read only with permission from the students. The intent of this was to observe students just writing and introduce them to composing in journals. Entries were collected and read approximately every two weeks until May 11. That was longer than originally planned, but the last entry collected was from the stem: "How can I use, in future classes, what I learned this semester about how I learn?" Other stems I used can be seen in Appendix B.

Middleton High School students are very comfortable with being tested. They are tested at least once per week all during the school year for several disciplines. Basic math skills are tested weekly via a computer format. So it seemed this would be a comfortable way for the students to provide pertinent information for this research. Upon consulting with Dr. Steven Dunbar, students were able to use his EDU webpage to conduct pre- and post-test topics of rectangles and the Pythagorean Theorem. The pre-test was conducted February 19 and the post-test was scheduled for April 12, but due to a conflict with the usage of the computers, it was

instead conducted on April 19. Some students were new at this time and had not taken the pre-test, so their information was excluded. The same result occurred with information of those students who “forgot” their password and could not complete the post-test. All students were used for this part of collection, so this was a good representation of the classes (see results in the graph in Appendix E).

The last method of data collection was student interviews and surveys (see Appendices D and C) if parent permission papers came back to the school and the teacher aides collected them and turned them in to the guidance counselor. The guidance counselor then randomly selected students for an interview. Each student was interviewed one time. Another teacher aide took the student out of the class into another room, read them the interview question and recorded their answer, which was then later transcribed. A point of frustration with this was that it seems the aide who conducted the interviews tended to lead the students’ responses. Many things entered into this time line. It really did not go as planned. Illness of the person collecting permission papers and the aide doing the interviews, the death of student’s parent, and spring break all interfered with the planned schedule. On April 10 the interviews finally began and were finished and transcribed by May 11.

Organization of data was challenging. Journal entries were collected and tally marks were recorded according to a pre-written rubric. Student interviews were transcribed and from that transcription tallies were counted and “lumped” into categories. Surveys were tabulated according to the survey, and pre-and post-tests were collected from Dr. Dunbar’s web page. Two pieces of data were analyzed quantitatively and reported through the use of mean and standard deviation. For the on-line test 45 students took the rectangles portion and 36 students took the Pythagorean Theorem portion of the pre- and post-test. Each test consisted of five questions. The

data collected in the student journals was analyzed qualitatively. Common themes were drawn and student examples of those were included.

Findings

What are the effects on student understanding of having students write explanations to math problems?

After collecting data about this question, the research showed that understanding increases when students write explanations to math problems. Evidence for this assertion includes pre- and post-test data, and material from student journals looking at cognitive level as graded according to entries on recount, summary or dialogue (Appendix A).

The pre-test was given on the Pythagorean Theorem and rectangles. All students got at least one point of the five possible. The most any student got was three points out of five possible. Work in the classroom continued on one of each of the problems from those tests as a "habits of mind" problem to begin each class. More involvement by all students is ongoing. When asked how they felt they did after the post-test, the students said they believed they did better because they understood it this time.

The results of the pre- and post-test on student understanding were as follows: In rectangles 45 students took the pre- and post-test. Each test consisted of five questions. Of the 45 students, 11.7% (5) that took these tests scored higher by three questions. Nine students (17.7%) scored two questions higher on the post-test. Forty percent of the students (18) improved his or her score by one question. Fourteen students scored the same on the post-test as the pre-test. That was 31.1% of the 45 who took both the pre- and post-test. The mean score was an increase of 1.08 questions. The standard deviation was 0.97286. This information translates into the fact that the average cluster of students scored one more question correct on the post-test within a little less than one standard deviation. Interestingly the median of the data was also one. This gives a

high degree of confidence to the results that a student who wrote about how they learn math, rather than simply working problems, would get on average one more question correct out of five questions on a pre-and post-test on rectangles.

Concerning the Pythagorean Theorem test, 36 students took the pre- and post-test. Each test consisted of five questions: (Only those students who took both the pre-and post-test were used in this data). The results were as follows: 2.7% (1) of the students scored four questions higher, 2.7% (1) of the students scored three questions higher, 8.3% (3) of the students scored two questions higher, 36.1% (13) of the students scored one more question, 22.2% (8) of the students scored the same, 19.4% (7) of the students scored one question fewer, 5.3% (2) of the students scored two questions fewer, and 2.7% (1) of the students scored three questions fewer. This data is not clustered as well as the data for rectangles. The mean was a positive 0.33 with a standard deviation of 1.414. The median score of 0.5 shows there was an improvement, but it was not as high as the improvement for the rectangle data. There was improvement over all for students who wrote about how to solve problems rather than just solving problems mathematically.

A think-aloud was conducted, but it is not included in the data. As the researcher listened to the tape recording, she heard the teacher aide leading the students. One example of this is when the student was asked to describe how the student would calculate the volume of a rectangular prism with a length of 11 inches, width of 4 inches and a height of 9 inches, one student's response was:

> "It'd be length times width times height, and it'd be equal to 296 inches squared." At this point you can hear the teacher aide tapping her pencil on the paper and asking "Squared?" and the student finishes, "Because it is volume, yeah it'd be inches cubed."

Another problem that was asked in the interview was: Calculate the altitude of a square based pyramid with a slant height of 13 feet and a side of 10 feet to which a student replied,

> "Well 10 and 13, is that right? (Aide says yes) So say, you'd use the Pythagorean Theorem so you'd take x squared plus10 squared equal 13 squared and then you'd just width plus height. Oh yeah, do you have to take the radius or what? (to which the aide replies no, just explain what you're doing) then when you get them both squared you'd take 100 from 169, which is…is that right x squared which comes out that x would be 144, oh x squared. (Aide then asks "and what is x"? Oh, it would be …(no further response from student.)

The feedback received from students about the effects on student understanding after having written explanations to math problems is very positive. Only four out of seventy-two students said they do not like the extra effort and see no rewards. All others, however, claim this method is helping them to understand better and follow step by step how to solve problems. They report that they see this as a study aide when they are solving problems. They have an organized place to look back to for examples. To guarantee every student is now taking notes, he or she is provided a bound notebook. Many students' responses are like this student's entry: "Taking notes helps me understand my homework better. It helps me because I can look back at examples that are in the notes. In the notes it explains how to do it so it's better taking notes."

Further, "Yes, taking notes does help. It gives me time to look over what the assignment is going to be about. Talking a little about the notes helps as well. That allows me to ask questions about something I might not understand."

Students stressed they could take the notes in a way they could understand. One student said it provides a way to look back and see their progress. Students do not like the extra work but they say they can see the benefits. But it is apparent that they have trouble taking notes. One student suggested that the teacher "give" notes one day and talk about them the next, that way they will be able to copy the notes in their notebook. They appear to have difficulty copying

notes and listening to an explanation at the same time. A point noteworthy here is that all students who said they did not like to take notes were students whose first language was English. All students for whom English is a second language said taking notes helped them. To be more specific, not all students for whom English is the main language spoken at home noted they dislike taking notes. Journals were graded using a rubric (See Appendix A). One disappointment was that entries fell mostly at the beginning phase. The majority of students were only able to regularly copy part or most, but not all, of the board notes into the journal. They could copy examples from the board, but they were unable to connect them without the teacher's guidance. The majority of students were able to ask focused questions to get help with particular difficulties. Only a few students were able to write brief entries on a regular basis.

How do students communicate understanding/frustrations of how they learn mathematics?

After collecting and analyzing data it was apparent that students felt more comfortable writing about their understanding/frustrations of how they learn mathematics than talking about them. The evidence includes the teacher's journal of tally marks to record number of appropriate examples and questions students used, a student interview about difficulties in communicating mathematical knowledge, and a student survey about perception of how well they were able to communicate their understanding of math.

At the beginning, the only frustrations were about taking notes, such as "It doesn't help me understand the concept any better than when I didn't take notes. I don't think it helps me any because I already know the concept good [sic] enough when we go over it before the assignment. I feel that that is the best way to help us understand the concepts".

All but two students communicated the fact that keeping a journal is helping them learn math. Some quotes from students: "I can look back on what knowledge has changed," "I know

how the problem is solved," "When I forget something I can look back and have an idea of what I'm doing." Journal entries provided evidence of students' attitudes toward writing in math journals such as, "I love to write about anything." Another said, "I was able to write how I feel about math." Those were some of the individualized quotes collected. Many of the others simply say, "I like writing in journals because I have something no one else can see and I can go back to look when I forget something." "Taking notes has helped me more because I am a visual person. I learn by seeing and doing things. I understand more about what you're talking about because I see what you're talking about and the problems."

One particularly informative quote was, "having notes when I am not in class is very useful, especially when there's worked out problems so I can see what it is that I'm trying to do. If you worked with me individually, it would help even more because I'm very shy at asking questions during class, or answering them for that matter, afraid to get it wrong." This attitude of being uncomfortable about asking questions in class was reflected in the math survey where half of the students who answered the question, "I feel comfortable asking questions in math if I don't understand a concept" rated themselves at a very low or below average level.

In the student interview when asked "Were you ever frustrated while writing out answers?" student responses were mixed. Responses included "Teachers explain better than students," "It took too long to write out," "Yes, a couple of times when I couldn't figure out the answer to a couple of problems," and "Sometimes I would because I wouldn't understand how to do it," as well as just "No."

When asked how successful they felt, most simply answered "Yes" while one student said "Very successful because it helps the teacher show me what I've done wrong and what I've done right. It also helps us to write better." When asked what the benefits are of writing out

homework, if any, students responded “Yes- don’t just work answers,” “Able to show I understand not just copy,” “To see what you do wrong or right,” and “To know what I’ve done wrong and what I’ve done right.”

All responses were represented basically by this student: “I’ve learned that many things help me, but it is different techniques for different chapters. This class over all has shown me to read the chapters and also take notes. In other chapters I may understand right away. Out of all of my classes over the years this class has taught me to take notes.”

The student interviews also included positive, useful comments. Most students responded positively to the question “Did writing out your answers help you understand anything?” Some of the more explicit responses were “Yes because I could tell what I am doing,” “Yeah it makes me fell like I improve,” “Yes, it did because I can understand what she says when she talks about a certain problem,” “Some of them do because I can go back and check and review.”

Again the majority answered positively to the question “How did writing out answers to math problems make you feel?” Some responses included “Nice, learned more,” “Ok helped understand better- easier but more work,” “Helped me remember things better,” “Understood more, better realize what to do,” “Good because now I can understand more-I am learning now,” “So I could check over to make sure I was doing it right, so I could review to learn more.”

Most responses to the question “What do you think is the purpose of math journals?” were positive as well. Here are some examples: “I understand,” “So you could remember for test,” “To help you understand problems better to keep notes in there,” “To teach you how to understand how we’re doing, what we’re doing, and what makes us learn better .”

Most responses to the question “Do you like writing journal entries? Why or why not?” were similar to this: “Yes- actually it helps because I can look back on my notes and it helps,” or

"Yes because it helps me to extend my vocabulary and I know more words than I use to," and "Actually I do because I can tell the teacher if I do good, or something if she might have to change."

What are the effects on students' attitudes toward mathematics of students writing math journals?

After collecting and analyzing data about this research question, it is obvious that attitudes toward mathematics improved. Evidence for this assertion includes student journal entries, student interviews, and a teacher journal to record observations of student writing responses to journal stems.

The students know the teacher is interested in what they have to say, but more importantly, they know he or she is interested in what they are learning, and they understand that by journaling he or she does want them to learn. Most students feel they are able to show the work required to solve math problems. Twenty-four of twenty-eight students indicated on a survey that they are able to show the work required to solve math problems at an average to above average level. Twenty-six of twenty-eight students believe math skills are important for other skills, the mode being fifteen of twenty-eight who ranked their ability above average. Most of the comments from the twenty-one students who filled out the question were very positive such as "Keeping a math journal has helped me to understand," "The work it takes to solve a problem," "How to work out the problems using different methods," "Why we do things," " It's helped me know how to set up equations and how to figure them out step by step," "The many possibilities of solving problems."

Only four of the students responded negatively. Some of their comments include "No it does not help me because I never looked at them," "Nothing really because I learn better from

listening and watching," "I don't really like keeping a math journal because it hasn't helped me to understand math any better."

Student interviews also provided positive feedback. A typical comment was "It helped a lot. It gave you better understanding and it's not just like you go over each problem quickly. You actually take your time on a problem, you write in a journal, and you can go back if you don't remember how to solve a problem you've written down, so you have a reference basically."

They do recognize it is a higher level of understanding as one student comments, "It takes longer if you don't really know how to solve a problem it is hard to write about the problem itself."

This research began with a process the teacher thought appropriate for "teaching" the students how to journal. It began with journal stems and having them write their opinion. There was no "right" or "wrong" answer. They were simply to write. It met with some resistance at first, and many were seen sitting and staring into space. There were examples of good responses, even if there were examples of someone saying they did not like math. Quality responses were used extensively. Students knew the teacher was interested in what they had to say; it did not have to be what they "thought" she wanted them to say. When they are asked to journal now, they get on task quicker and write for longer periods of time. However, it did not take long to discover that "Just because students are in high school doesn't mean they know how to take notes." The teacher was oblivious to this earlier in the year and just thought because notes were on the board, students were "getting" them. The goal, realizing that students did not know how to take notes, was to take notes in their journals. Students kept a math journal of notes as each new topic was introduced. They were encouraged to add examples, underline or write a more in-depth

explanation, which could be as simple as drawing a picture so that students could understand it in their own words. The teacher evaluated this as a “recount” level entry in her personal journal.

Conclusions

It seems the system has been so caught up teaching students the English language here in Middleton so they can score higher on tests, that teachers have neglected to show them how to take notes and ask questions so that they can take responsibility for their own learning. The reason this project was chosen was to see how many students are simply copying answers. The system has made math about the right answer, not the process along the way. Students need to understand what they are doing in order to progress mathematically. The fear of not “covering all the curriculum” should be secondary to teaching students how to think and analyze, so they will gain confidence and be able to learn even after they leave these classes. The classroom is not about the teacher; it is about the students and their learning.

Students were asked to do a final journal entry because the next step for them was to connect what has been done to their own learning. The question was, “How are you going to use what you learned about how you learn in your future classes?” Many students did not really understand all that was done to help them with their own education. Many students simply wrote what they thought the teacher wanted to read, or they wrote complimentary things about how they learn best the way they were taught. Three students “got it” as shown below.

> Throughout the year, I’ve learned about many different ways of learning. I’ve been able to learn easier by writing rather than just simply solving problems. It is easier for me to learn through demonstration or step-by-step process. This year has been a building block for me because I’ve learned a lot.

> The way that I learned this year was by repeating everything I did. Repetition was the key to my learning because once you do something one time you have an image of how it’s going to look. That is why it is easier to determine the outcome. Also I had a teacher that would not let me give up. Hopefully now I can use some of the skills that I’ve learned over the last year.

> I have learned many things this year and don't plan on forgetting them. I will probably even decide to keep the journal we've worked on throughout the semester because I found it of much use and took pretty good notes in there that I understand.

In this teacher's opinion much of the writing reveals, just as Middleton and Spanias (1999) found in their study about reasons for motivation in math, "Students tend to rate mathematics as less fun as they go from elementary to junior high to high school" (Middleton and Spanias, p. 67). At the high school level, one wants to find a way to motivate students and build their confidence. There is a strong correlation between confidence and how well a student does in math class.

> In short, when teachers emphasize understanding of mathematical concepts and provide facilitative classroom environments, students tend to be more receptive and less anxious with regard to mathematical activities than when teachers stress rote activities and are perceived to be authoritarian. Students who have good experiences in mathematics tend to be less math-anxious and less inhibited in pursuing mathematics-related careers than students who have bad experiences. In mathematics, perhaps because it is viewed as a difficult and important subject, students tend to internalize their experiences into their self-concept more than in other subject areas" (Middleton, Spanias, 1999, p.76).

Implications

Middleton and Spanias (1999) stated that students must feel comfortable with math, must be challenged to achieve, and must expect to succeed. This teacher's concern is that when students see themselves capable of doing well in math, they will tend to value math more. Students become frustrated when procedures do not happen immediately, and press the teacher for more guidance, which defeats the purpose of using a complex problem in the first place and reduces opportunities for students. But, if a less complex problem were used, students would not be provided the same opportunities to engage in mathematical thinking. To challenge students, therefore, the first thing this teacher plans to do is keep a journal in order to find ways to

encourage and support students as they struggle with the limitations of their current ways of knowing.

Students should benefit from classroom activities. The research shows that the real benefit from writing activities may not be in the writing, but the activities that require student's to struggle in order to understand mathematical ideas well enough to communicate their understanding to others. This research strengthens the affirmation that Middleton students had to communicate their thinking in order to move them to a higher cognitive level. They will therefore be required to keep a journal.

They will also continue to be asked to keep notes, which will include a description of what they have learned, summarize key topics, and identify appropriate examples and questions. Regular monitoring of the journals will drive instruction and provide the basis for discussion with students individually as well as with the whole class when appropriate. Some of the greatest challenges will be to allow students time to think through a process, thus allowing the teacher to cover the curriculum in a way other than getting through the text cover to cover. In the little writing required this school year, students showed frustration with not being able to complete a task with perfection immediately. That may cause problems because this teacher is a "fixer" and wants to alleviate their feelings of frustration. The research studied and applied in this project indicates that is the exact wrong thing to do. So attempts to change things in the classroom include both bringing students to a higher level of cognitive understanding as well as teaching their teacher to become a better instructor through the use of journals.

Student journals provide such valuable information that this teacher would advocate other teachers implement the use of journals in their classrooms. Data shows students, for whatever reason whether shyness, lack of background information, or even inadequate spoken language

attainment, are not asking questions in order to achieve at a level they are capable. A simple beginning would be to have students take notes, to ensure students understand what they are being told. Teachers in all disciplines give notes. Time at the beginning of the year teaching students how to take notes would be time well spent. Teachers cover a vast amount of material and concepts. It is time to work smarter. If students are taught how to take responsibility for their own learning, teachers can concentrate on teaching the materials. This teacher believes that having students learn early how to write out notes, thought processes and even questions will help guide responsibility for student learning back to the student. The teacher would not have to monitor the journals at all times; a “think-pair-share” strategy could be used so that students could talk and listen to each other to resolve minor questions. When necessary, the instructor could step in to ask guided questions, or direct student thought. The time taken to implement this will also give the teacher a better idea if the student is “getting” the concept being presented and thus more accurately be accountable for each student’s learning. Although it may take some extra time at the beginning of a school year, it would be very beneficial and useful throughout all disciplines. Grading could be a quick check to see that students are journaling, or an occasional graded comment would be sufficient. Alternately, the teacher may wish to implement a policy to read only those journals students ask them to read. An added bonus is the amount of information learned about the students.

References

Alcaro, P. C., Alston, A. S., & Katims, N. (2000). Fractions attack! Children thinking and talking mathematically. *Teaching Children Mathematics, 6*(9), 562-67.

Andrews, A. G. (1997). Doing what comes naturally: talking about mathematics. *Teaching Children Mathematics, 3*(5), 236-39.

Baxter, J. A., Woodward, J., & Olson, D. (2005). Writing in mathematics: an alternative form of communication for academically low-achieving students. *Learning disabilities Research and Practice, 20*(2), 119-135.

Bishop, A. J. (2002). Critical challenges in researching cultural issues in mathematics education. *Journal of Intercultural Studies, 23*(2), 119-131.

Buerk, D. (2000). What we say, what our students hear: a case for active listening. *Humanistic Mathematics Network Journal,* (22), 1-11.

Ciochine, J. G., & Polivka, G. (1997). The missing link? Writing in mathematics class! *Mathematics Teaching in the Middle school, 2*(5), 316-320.

Clarke, D. J., Waywood, A., & Stephens, M. (2003). Probing the structure of mathematical writing. *Educational Studies in Mathematics, 3*, 235-250.

Dominguez, H. (2005). Bilingual students' articulation and gesticulation of mathematical knowledge during problem solving. *Bilingual Research Journal, 29*(2), 269-293.

Harlen, W., & Crick, R. D. (2003). Testing and motivation for learning. *Assessment in Education, 10*(2), 172-199.

McCaughtry, N. (2005). Elaborating pedagogical content knowledge: what it means to know students and think about teaching. *Teachers and Teaching: theory and practice, 11*(4), 379-395.

Middelton, J. A., & Spanias, P. A. (1999). Motivation for achievement in mathematics: findings, generalizations and criticism of the research. *Journal for Research in Mathematical Education*, 30(1), 65-88.

Neria, D., & Amit, M. (2004). Students' preference of non-algebraic representations in mathematical communications. *International Group for the Psychology of Mathematics Edcuation* , 8 p.

Pressley, M., Symons, S., Snyder, B. L., & Cariglia-Bull, T. (1989). Strategy instruction research comes of age. *Learning Disability Quarterly, 12*(1), 16-30.

Stonewater, J. K. (2005). Inquiry teaching and learning: the best math class study. *School Science & Mathematics, 105*(1), 36-47.

Appendix A

Table of progress descriptors for student journal use

Summary	Exemplification	Questioning	Application
Able to regularly copy part or most of the board notes into the journal.	Includes copies from board or from exercises, but unable to connect them with journal entry.	Asking questions that are unfocused. E.g. How do you do algebra? How do you do these things?	Writes short entries about occasional lessons.
As above but also able to describe Important aspects of what was done in class.	Able to choose appropriate practice exercises as examples to illustrate the content of the lesson.	Able to ask focused questions to get help with particular difficulties.	Writes brief entries regularly.
Able to record of the main ideas of a lesson and able to write some thoughts about them.	Able to use examples to show how a mathematical procedures is applied.	Able to ask questions about mistakes or misunderstandings that lead to a discussion of the underling idea.	Maintains regular entries that give adequate coverage of the day's lesson.
Able to isolate and record known words a sequence of connected ideas from a lesson, with an emphasis on expressing mathe-matical learning.	Able to choose important examples and show clearly how the examples illustrates the mathematics being used and how it works.	Able to ask questions that explore consequences or extend ideas E.g. What if?	Maintains regular entries that often explore or extend the materials covered in Class.
Able to formulate and state an overview of material covered in a lesson, text, or topic with appropriate use of formal language and vocabulary.	Able to choose relevant mathematical examples to illustrate points in the discussion of an idea.	Able to ask questions that are aimed at linking one part with another.	
Able to extrapolate from material presented in class in a text, and reshape it in terms of own learning needs.	Able to choose examples that summarize important aspects of topic, idea, or application. These examples are fully annotated to show their relevance.	Able to pose clearly mathematical questions. That is questions that are appropriate to the discipline of mathematics, in a mathematical way.	

Appendix B
Student

What I like about writing in a journal rather that solving problems is…..

What I don't like about writing in a journal is…..

I was surprised to discover……

I like working with others rather than writing in a journal, especially when……

Even though I don't like to write in a journal, I found out that it helped me understand……..better.

Taking notes helps me understand math better. (Y/N) Why or why not?

I stopped liking math in…….

Write a word explanation to problems2 and 7. Describe in words how you solve them.

Appendix C

Please give your honest response to each statement, 1 being low and 5 being high. Please DO NOT put your name on this paper. Responses to this survey will be anonymous.

1. I like math.	1	2	3	4	5
2. I am good at math.	1	2	3	4	5
3. Math skills are important for other skills.	1	2	3	4	5
4. I am able to show the work required to solve math problems.	1	2	3	4	5
5. I like to answer questions asked in math class.	1	2	3	4	5
6. I feel comfortable asking questions in math if I don't understand a concept.	1	2	3	4	5

Complete the following statements:

7. Keeping a math journal has helped me to understand…

8. I liked this best about keeping a journal…..

9. I liked this about keeping a journal least…..

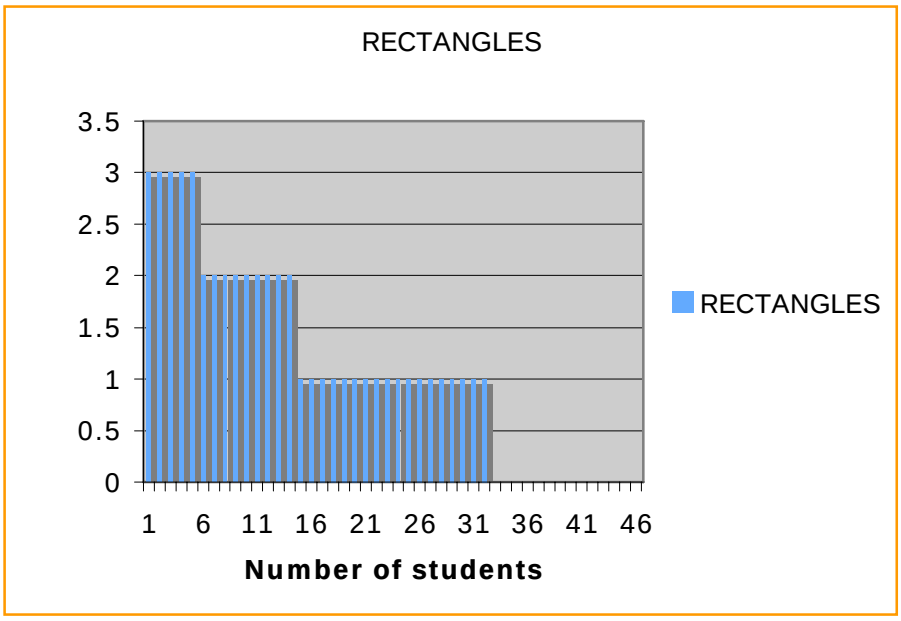
Appendix D

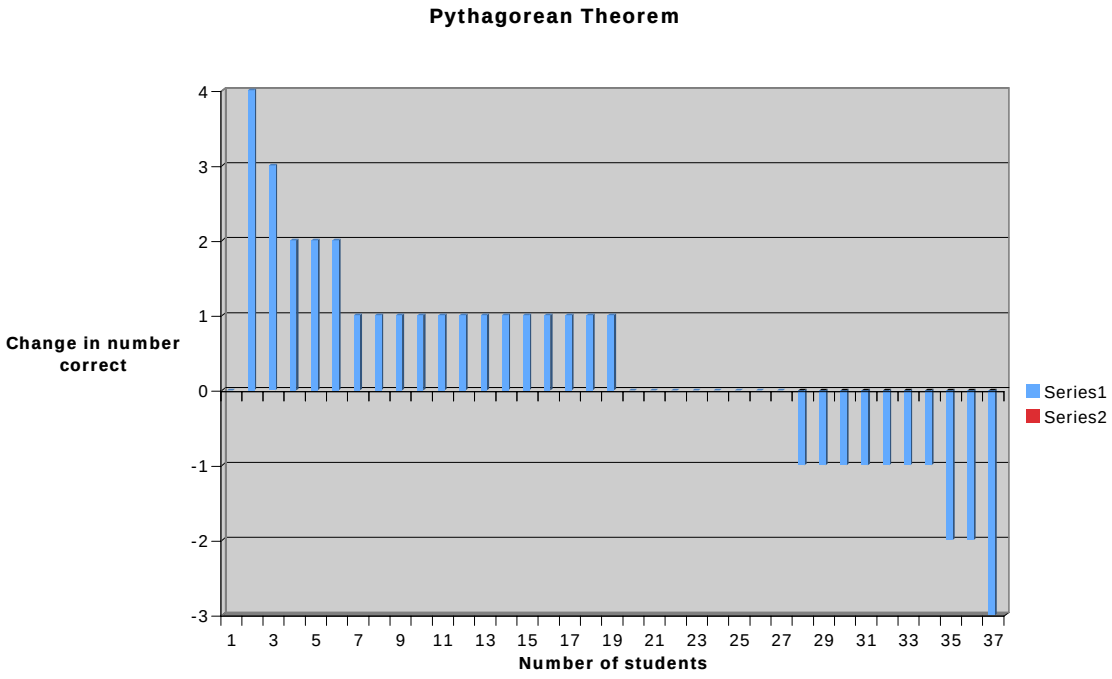
Student Interview Questions

Student interviews will be focused on a subset of these questions.

1. How did writing out answers to math problems make you feel?
2. What do you think is the purpose of math journal?
3. Do you like writing journal entries? Why or why not?
4. Was writing easy for you? Why or Why not?
5. What are the benefits of writing your answers on your homework assignments, if any?
6. How successful do you feel about writing out answers to math problems?
7. Did writing out your answers help you understand anything?
8. Were you ever frustrated while writing out answers?
9. If you were frustrated, did you ask for help? If so, who did you ask? How did they help you?
10. When writing out a problem, do you think you know the meaning of most of the vocabulary words in each problem?
11. Why is it important to know the meanings of vocabulary words you see in math?
12. Have you ever written out solutions to math problems before this school year?
13. Has your attitude about writing solutions to math problems changed during this school year?
14. If your friend had been absent from class when we _____, how would you explain I to them?
15. If you saw your friend had this answer on this problem, how would you explain their mistake to them?
16. Is there anything else I should know about how you learn to better understand your problem solving in math or your general math experience?
17. Emma is saving money to buy a bike that costs $72. She wants to buy the bike after saving the same amount of money each week for 6 weeks. How much money does she need to save each week?
18. Calculate the altitude of a square based pyramid with a slant height of 13 feet and a side of 10 feet.
19. Calculate the volume of a rectangular prism with a length of 11 inches, width of 4 inches and a height of 9 inches.

Appendix E


RECTANGLES
3.5
3
2.5
2
1.5
1
0.5
0
1 6 11 16 21 26 31 36 41 46
Number of students
RECTANGLES


Pythagorean Theorem
Change in number correct
4
3
2
1
0
-1
-2
-3
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37
Number of students
Series1
Series2